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# ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

INDEXED

Final Report

On

PROJECT NO. T-11 - TEST OF HEAT LOAD IMPOSED BY CLOTHING  
TREATED TO REPEL INSECTS AND ARACHNIDS

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Project No. T-11

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27 September 1945

Serial

U.S. Armored medical research Laboratory,  
Fort Knox, Ky.

Project No. T-11

ARMORED MEDICAL RESEARCH LABORATORY  
Fort Knox, Kentucky

SPMEA 727-2  
Project No. T-11

27 September 1945

1. PROJECT: No. T-11 - Final Report on Project No. T-11, Test of Heat Load Imposed by Clothing Treated to Repel Insects and Arachnids.

a. Authority: Letter, Office of The Surgeon General, Washington 25, D. C., 1st Indorsement, File SPMDO, dated 7 June 1945.

b. Purpose: To determine the physiological heat load induced by the wearing of insect repellent clothing.

2. DISCUSSION:

The Army Committee for Insect and Rodent Control desired studies on the physiological heat load of a new insect repellent herringbone twill uniform. Preliminary investigations had shown that the benzyl benzoate, vinylite resin impregnation submitted for test was effective and resisted laundering. It was the purpose of this study to determine whether or not this impregnation imposed a heat load on troops wearing the garment in hot environments.

3. CONCLUSIONS:

a. Herringbone twill uniforms impregnated with 5% benzyl benzoate and 5% vinylite resin do not impose any greater heat load on acclimatized men than ordinary herringbone twill. Tests were performed in both hot dry (D.B. 120°F., W.B. 86°, R.H. 26%) and hot humid (D.B. 88°F., W.B. 84°F., R.H. 85%) environments.

b. All of the subjects complained of skin irritation produced by the new impregnated fatigues.



4. RECOMMENDATIONS:

That if the Chemical Warfare Service tests in progress indicate that this impregnation is not lost by continued wear and laundering, and does not produce a serious dermatitis, these insect repellent garments be considered suitable for issue.

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1. SUBJECTS, EXPERIMENTAL CONDITIONS AND PROCEDURES:

This investigation was conducted in the laboratory hot room during August and September 1945. Twelve normal healthy soldiers were studied. Their ages ranged from 20 to 31 years (average 25); heights from 67 to 71 inches (average 69); weight from 135 to 190 pounds (average 155) and surface areas from 1.7 to 2.0 square meters (average 1.9).

The clothing was tested on men in two different environments which were representative of two types of hot climates.

- a. Hot dry - D.B.  $120^{\circ}\text{F.}$ , W.B.  $86^{\circ}\text{F.}$ , R.H. 26%
- b. Hot humid - D.B.  $88^{\circ}\text{F.}$ , W.B.  $84^{\circ}\text{F.}$ , R.H. 85%

Throughout the tests, the dry and wet bulb temperatures were measured every fifteen minutes with four motor driven fan psychrometers at a level of four feet from the floor. The values rarely varied from the desired dry or wet bulb temperature by more than  $1^{\circ}\text{F.}$  The temperature of the walls, floor, and ceiling was measured twice daily. In the  $120^{\circ}\text{F.}$  environment the average of these measurements was  $116 \pm 1^{\circ}\text{F.}$  and in the  $88^{\circ}\text{F.}$  environment the average was  $87^{\circ} \pm 0.3^{\circ}\text{F.}$

A mildly turbulent air movement in all parts of the room resulted from combination of hot air inflow from four anemostats in the ceiling and four 16-inch fans operating on the floor in the center of the room. Wind velocity was not measured but was essentially that produced by the movement of the men marching at 3 mph.

The men lived in barracks and were in the hot room five hours each day. The standard test work consisted of carrying a 20-pound pack and walking for four continuous hours at 2.9 mph around a 67 foot track in the hot room. This work rate was previously determined to be approximately 250 Calories per hour. Acclimatization to the heat was achieved by having the men march in the hot room for 25 days before the clothing was tested. Afternoon marches were taken to attain physical fitness.

All water drunk during the test periods was a 0.1% solution of sodium chloride. In the  $120^{\circ}\text{F.}$  environment the saline solution was kept at a temperature of  $96^{\circ}\text{F.}$ ; in the  $88^{\circ}\text{F.}$  environment, it was kept at  $88^{\circ}\text{F.}$

A Latin Square method of testing was used. Each of the men wore new insect repellent herringbone twill fatigues and new untreated herringbone twill uniforms once in each of the two environments. The insect repellent uniforms had been treated with 5% benzyl benzoate and 5% vinylite resin and showed an add-on of about 20%. This impregnation has been shown to be effective and to resist laundering. The test clothing had not been laundered.



The clothing was always worn in the same manner to give greatest protection against insects; trouser legs were tucked inside of the pulled up socks, jacket shirt tucked into the waist of the trousers, and top button of the jacket buttoned. Since this reduced bellows action of clothing and gave maximum cover these tests were carried out with the clothing imposing a maximum heat load at the given environment.

Upon arrival in the morning, the men remained in a room at 75°F. until individually called into the hot room 8-10 minutes before beginning to walk. Each man entered the hot room completely nude, urinated, dried off any sweat present and was weighed (within 10 grams). Simultaneously the jacket and trousers he was to wear (placed in the hot room 30-45 minutes earlier) were individually weighed (within 5 grams). The subject quickly dressed in these garments and stood erect 4 minutes during which the heart rate, rectal temperature and skin temperature were determined. He then began marching. During the walking period all water drunk, urine voided and vomitus were carefully measured. At hourly intervals, the heart rate and rectal temperatures were determined. After 4 hours of walking, the subject stood erect while the heart rate, rectal temperature and skin temperature were measured. He then stripped completely, urinated, dried off all of the sweat and was weighed. At the same time, his removed clothing was weighed. Throughout the entire test, records were kept of the general appearance and reactions of the men.

The skin temperature of five areas of the body, three covered and two uncovered (chest, forearm, calf, cheek, palm) were determined with a radiometer. For clothed areas, the clothing was pushed aside just sufficiently to permit placing of the radiometer. Undue exposure of clothed areas was avoided. The skin temperatures of individual areas were integrated into an average skin temperature by the following weighting formula based on the original formula of Hardy: Chest 0.44; forearm, 0.14; calf, 0.23; cheek, 0.10; palm, 0.09. Henceforth the term skin temperature will refer to this weighted average skin temperature. Rectal temperatures were measured with calibrated rectal thermometers.

## 2. RESULTS:

### a. Heat Load at a High Dry Bulb Temperature:

D. B. 120°F., W.B. 86°F., R.H. 26%

This environment simulated that found in buttoned-up tanks operating in the summer at Camp Polk. The humidity is higher than that found in desert environments. The responses of the men working at this temperature show that impregnation imposed no added heat load on the men (Table I).

### b. Heat Load at a Low Dry Bulb Temperature:

D. B. 88°F., W.B. 84°F., R.H. 85%



This simulates a typical tropical environment. Again the responses of the men indicated that the impregnation imposed no added heat load (Table 2).

c. Physical Characteristics of the Clothing:

(1) Gross Characteristics:

The insect repellent clothing resembled untreated herringbone twill in appearance (Photographs 1 and 2). The fabric was slightly more coarse than herringbone twill and it had a pungent odor. However, none of the men in the test had any complaints about the odor. The intensity of the odor diminished greatly during two wearings. It is possible that the passage of large quantities of sweat through the garment leached out some of the active agent.

(2) Absorption of Sweat:

The following table presents the average data on 12 men and their clothing:

Test	Clothing	Average Four-Hour Sweat Loss per Man (Grams)	Clothing Uptake of Sweat (Grams)	Percent of Total Sweat in Garment
D.B. 120° W.B. 86°	Insect Repellent Uniform	7,774	653	9
	Herringbone Twill Uniform	7,035	883	13
D.B. 82° W.B. 84°	Insect Repellent Uniform	3,410	778	23
	Herringbone Twill Uniform	3,300	1,037	31



Similar patterns in sweat uptake by the clothing occurred in both environments. In neither environment was this uptake equivalent to the water absorption capacity of the clothing, as determined by immersion studies.

The sweat uptake characteristics of the insect repellent garment are satisfactory, although slightly inferior to those of the herringbone twill uniform. The water repellency of the treated garment was manifested by the greater accumulation of sweat in the shoes resulting from funneling of sweat down the legs. The amount of sweat in the shoes at any time was dependent on the sweating rate of the individual. The high sweating rate of the right hand subject in Photograph 3 resulted in sweat being squirted from the shoes even before he had marched a single hour.

#### d. Skin Irritation Induced by Insect Repellent Clothing:

All men complained of skin irritation when wearing the treated clothing. This was localized to the areas of contact. Only a transitory erythema was noted in the involved areas. The irritation was generally described as similar to having sandpaper rubbed over the skin.

One man wore the insect repellent clothing for four hours on each of seven days. He complained of minor irritation on each wearing. Some men found that wearing an undershirt eliminated much of the discomfort associated with the garments. Further work on skin irritation was not conducted as extensive studies are being done elsewhere.



TABLE 1

The Physiological Responses of Wearing Men Clothed in Insect Repellent and Standard Herringbone Twill

D.B. 120°F - M.B. 86°F - R.H. 26%

CLOTHING	NAME	RECTAL TEMPERATURE °F					PULSE RATE/Min.					WET WEIGHT LOSS (Gm/hr.)		
		Hours					Hours							
		0	1	2	3	4	0	1	2	3	4			
HERRINGBONE TWILL UNIFORM	Abb	98.8	100.5	100.5	101.6	100.9	90	123	111	107	111	96.6	97.0	2080
	Aur	98.6	100.9	100.9	101.1	100.7	102	117	126	120	117	97.1	97.3	1689
	Dlg	98.0	100.0	100.1	100.0	100.1	87	117	120	114	117	96.4	96.1	1720
	Itw	90.3	100.3	100.1	100.0	99.9	87	101	120	117	120	96.4	96.3	1678
	Mam	98.6	100.9	101.1	101.3	101.4	96	120	117	123	129	96.4	97.3	1644
	Miv	97.9	100.4	100.5	97.9	100.3	105	114	117	120	120	96.7	96.9	1525
	Wcb	98.6	100.0	100.5	100.5	100.6	99	123	126	120	108	96.4	98.6	1500
	Wel	98.0	100.4	100.3	100.3	100.3	102	114	114	108	111	97.4	98.1	1571
	Moo	97.7	100.6	100.6	100.6	100.3	96	123	120	111	117	98.3	98.2	1452
	Pop	98.3	100.7	100.8	100.5	100.3	105	117	114	111	124	97.6	97.9	1788
	Ths	98.4	100.0	100.1	100.1	100.0	100	117	108	114	114	96.8	96.0	1792
	Tho	98.3	101.0	100.7	100.6	100.4	99	120	105	111	117	97.6	98.7	1624
AVG.		98.3	100.5	100.5	100.5	100.4	98	117	117	115	117	97.0	97.5	1645
INSECT REPELLENT UNIFORM	Abb	98.2	100.6	100.7	100.7	100.7	108	108	123	114	105	97.2	96.5	2371
	Aur	98.7	100.9	100.5	100.5	100.0	102	111	114	105	108	96.4	97.5	1689
	Dlg	97.9	100.4	100.2	100.2	100.2	102	117	117	117	132	96.3	97.1	2007
	Itw	98.0	100.4	99.7	99.9	100.0	96	120	117	117	108	96.6	97.8	1554
	Mam	98.9	101.0	101.2	101.2	100.9	108	120	120	120	123	97.3	97.3	1671
	Mar	98.1	100.4	100.1	100.0	99.9	105	114	120	114	117	97.1	96.9	1451
	Meb	99.0	101.1	101.3	101.0	101.4	105	123	126	129	135	97.9	99.0	1173
	Mol	98.3	100.7	100.6	100.8	100.5	102	126	114	114	114	97.5	97.5	1528
	Moc	97.6	101.4	100.8	100.9	100.8	93	123	111	111	120	97.7	97.4	1546
	Pop	98.5	100.4	100.0	100.1	100.1	90	120	120	114	108	97.3	97.1	1799
	Ths	98.8	100.4	100.5	100.7	100.5	99	114	114	120	117	97.4	97.2	2126
	Tho	98.6	101.4	101.8	101.1	101.4	105	123	117	120	117	97.3	99.3	1476
AVG.		98.4	100.8	100.6	100.6	100.5	101	118	118	116	117	97.3	97.6	1696



TABLE II

The Physiologic Responses of Working Men Clothed in Insect Repellent  
and Standard Herringbone Twill

D.B. 88°F - W.B. 84°F - R.H. 85%

CLOTHING		RECTAL TEMPERATURE °F					PULSE RATE/MIN.					SKIN TEMP. (Avg. Wet.) °F		WETBULB LOGS (Sweat) (cm/hr.)	
NAME	Hours	Hours				Init. 4 Hr.	cm/hr.	Hours					Init. 4 Hr.	cm/hr.	
		0	1	2	3			4	0	1	2	3			4
HERRINGBONE TWILL UNIFORM															
Abb	98.4	99.7	99.7	99.8	99.9	87	102	99	93	96	93.7	94.1	134.1		
Aur	98.6	99.7	99.6	99.5	99.6	90	93	90	99	93	95.0	94.0	997		
Dlg	98.0	99.3	99.5	99.4	99.6	90	90	90	96	93	93.4	94.3	970		
Irw	98.7	99.6	99.5	99.6	99.6	102	99	99	93	96	93.6	93.8	768		
Kob	99.1	100.0	100.3	100.5	100.8	117	99	99	111	117	93.8	95.1	655		
Mun	98.7	100.5	100.5	100.6	100.5	117	120	117	117	114	94.7	94.7	761		
Mar	98.4	98.9	99.6	99.4	99.6	96	96	99	99	96	94.6	94.0	652		
Mol	98.4	99.6	99.6	99.9	100.0	93	99	93	84	84	95.2	94.5	670		
Moo	98.1	99.8	99.9	99.9	100.2	87	93	87	84	87	94.3	94.0	802		
Peb	98.1	99.5	99.6	99.6	99.7	102	102	99	102	108	93.2	94.7	639		
Tho	98.7	99.6	99.5	99.7	99.7	105	108	105	93	93	94.1	93.0	898		
AVG.	98.5	99.6	99.8	99.8	99.9	92	99	97	96	98	94.1	94.2	789		
INSECT REPELLENT UNIFORM															
Abb	98.2	99.4	99.6	99.4	99.7	81	96	105	102	108	94.9	95.0	1327		
Aur	98.7	99.9	100.0	99.9	99.8	102	102	99	96	93	95.5	94.4	586		
Dlg	98.3	99.5	99.7	99.8	99.8	102	99	99	99	105	93.9	94.4	1165		
Irw	98.1	99.2	99.4	99.3	99.7	99	102	99	105	105	93.3	93.5	806		
Kob	99.5	100.6	100.8	101.0	101.1	111	114	117	114	108	94.4	95.2	606		
Mun	99.4	100.9	100.7	100.9	101.1	108	114	108	111	111	95.9	95.1	753		
Mar	98.4	99.5	99.4	99.6	99.4	102	96	105	102	105	95.7	94.6	515		
Mol	98.3	99.6	99.6	99.5	99.9	96	108	99	102	99	94.1	95.2	601		
Moo	98.3	99.9	100.0	100.0	100.2	87	93	93	96	99	94.5	94.0	644		
Peb	97.9	99.6	99.7	99.4	99.3	87	111	111	108	99	93.9	94.9	743		
Tho	98.4	99.4	99.5	99.3	99.3	99	96	96	90	96	94.4	94.4	926		
AVG.	98.3	99.8	99.8	99.8	99.9	92	104	104	103	103	94.6	94.6	794		

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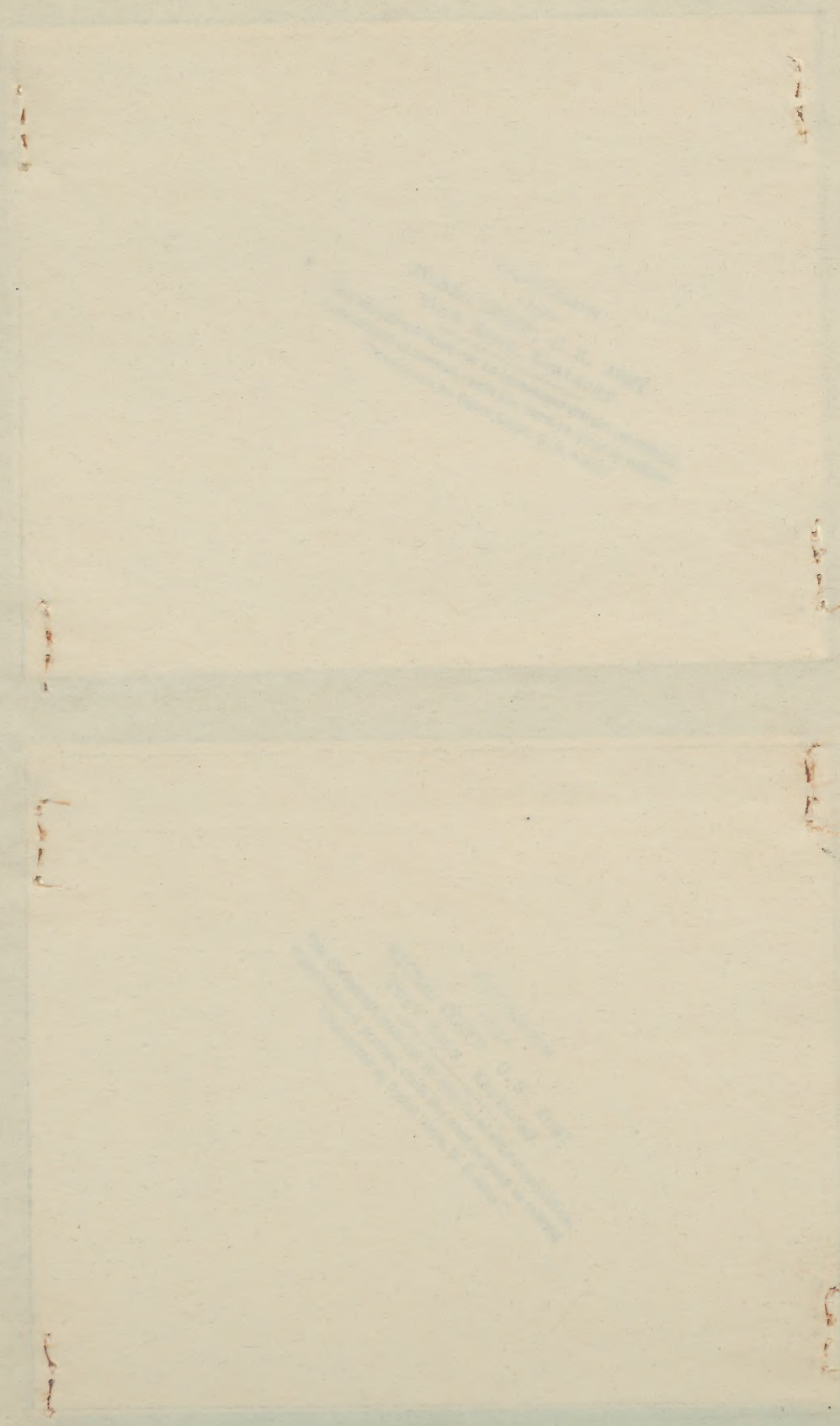
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New berkeley (left) uniforms before (left) and  
after (right) four hours of wear at 120°F. - 65%  
ARMORED MEDICAL RESEARCH LABORATORY  
FORT MON, KY.  
Photograph No. 1



New forest (left) uniforms before (left) and  
after (right) four hours of wear at 120°F. - 65%  
ARMORED MEDICAL RESEARCH LABORATORY  
FORT MON, KY.  
Photograph No. 2





Insect repellent uniforms after one hour  
of wear at 120°F. - 86°F.

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Photograph #3

*Incl # 3*

